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Department of
Agriculture

Rural
Electrification
Administration

REA Bulletin
Number
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Guide Specifications for Steel Pole Structures

June 24, 1983

FOREWORD

This guide specification has been developed to provide REA borrowers and their consulting engineers with the essential elements of a specification for the procurement of single shaft steel pole structures. The user should add, delete, and/or modify as appropriate for a particular transmission line and borrower's requirements.

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INSTRUCTIONS WHEN USING REA GUIDE SPECIFICATIONS FOR STEEL POLE STRUCTURES

A. Purpose

The intent of this Guide Specification is to provide a basis for procuring adequate steel pole transmission line structures. If competitively bid, use of this Specification should eliminate ambiguities which might arise in the evaluation process.

The Owner's Engineer or Representative is responsible for completing and/or adding to this Specification as appropriate. It may be necessary for this Specification to be modified in order to consider special applications or preferences of the Owner.

B. Scope

This suggested purchase Specification covers the technical aspects of design, materials, welding, inspection and protective coatings of single circuit steel pole structures, 115 kV to 230 kV. It does not include front-end documents or specifications for construction. The User of this Specification must add front-end documents including any supplemental instructions to the bidders and general conditions. This Specification may be expanded to include double circuit structures, structures over 230 kV, and H-frame structures.

C. Information to be Completed by the User

The Owner or Owner's Representative when using these specifications should detach sheets la to 7a and the Appendices, and complete the following:

1. Documents and general information to be added to the technical Specification:

   a. REA Form 198 (Recommended for competitive bidding)
   b. Supplemental Instructions to Bidders
   c. General Conditions

   A number of front-end documents and general information need to be added to the technical Specification. When there is competitive bidding, it is recommended that REA Form 198 be used. This form covers "Notice and Instructions to Bidders," "Proposal," and "Equipment Contract." Other supplemental information which the User may want to add would include "Bid Submission," "Bid Price," and "Schedule," "Bid Acceptance Period," "Bid Requirements," "Bid Data," and "Bidder's Qualifications." A section on General Conditions should be included to cover such items as "Definition of Terms," "Inspection and Acceptance," "Interpretation of Bid Documents," "Addenda to the Bid Documents," "Insurance," "Method of Payment," "Quantities," and "Tabulation of Unit Prices."

2. Requirements to the technical Specifications to be completed by the Borrower or Borrower's Representative and supplied to the Bidders:

a. Configuration Requirements and Other Information (Attachment A of the Specification)

(1) Structure dimensions
(2) Conductor support locations
(3) Shield wire support location(s)
(4) Structure details
(5) General load information

TUS-series drawing, page 5a, gives minimum dimensions. Greater values may be necessary to improve insulator swing or galloping performance. The distance from the top phase to the static wire is for a 30° shielding angle. For structures of heights greater than 75 feet, the angle should be decreased. For high isokeraunic levels or high ground resistance, use the number of bells in the second column under each voltage level in Tables 1 and 2. Drawings TM-S1 and TM-S5, pages 6a and 7a, give typical structure details.

b. Structural Requirements

(1) Design loads, with and without overload capacity factors (Attachment B of the Specification)

Minimum loadings shall meet the following requirements: (a) the National Electrical Safety Code District Loads with the appropriate overload factors; (2) extreme wind from any direction with an overload factor of 1.1; and (3) extreme ice conditions with an overload factor of 1.1. An appropriate gust factor shall be applied to wind velocity when considering wind on the structure. Crossarms shall be able to sustain a minimum weight of a 250-pound man when conductors are loaded with ice.

All structures shall have sufficient strength before stringing to withstand the extreme wind velocity multiplied by an appropriate gust factor. The structure shall be capable of withstanding this load from any direction. The vertical, transverse, and longitudinal loads for any given condition shall be applied simultaneously.

The everyday loads for 60°, no wind, should be specified so that proper arm design and/or camber design can be made. Loads without overload factors are required so that the manufacturer can supply appropriate base reactions with and without overload capacity factors (page 10, item 4.2.d).

(2) Pole deflection limitations, if any, page 4.

If deflection limitations are required, specify the loading condition(s) without overload factors, and acceptable means of achieving (raking, cambering, stiffening).

(3) Desired foundation type (direct embedded or anchor bolt type), page 4.

If embedded, the embedment length should be furnished by the Engineer. If anchor bolt type, strength of the concrete should be specified. The engineer may also want to specify the maximum anticipated foundation rotation and groundline deflection. If different for individual loading cases, indicate quantities in the loading tables (Attachment B of the Specification). The Supplier should consider them in the design of the poles when specified.

(4) Location, orientation, slope, type, size and strength of guys, if any (Attachment A).

c. Other Requirements

(1) Special Charpy requirements, page 4.

(2) Diameter and taper limitations, if any (point-to-point diameter for other than a round cross section), page 4.

(3) Desired method of surface protection, page 4. If a special corrosion problem exists, this should be mentioned, along with the recommended solution.

(4) Preference of climbing ladders or working ladders, page 4. Also, quantity of removable ladders to be supplied with the poles should be specified.

(5) Structures to be tested, if any, and number of load cases for each structure test. Page 8, items 3.6a and 3.6b.

(6) Component weight and/or length restrictions, if any, page 4.

(7) Delivery schedule and F.O.B. location, page 4.

(8) Miscellaneous, page 4. (Additional items such as special attachment requirements, grounding requirements, climbing devices, hot line maintenance requirements, etc.)

D. Information to be Completed by the Manufacturer

The Owner or Owner's Representative should have the following information completed by the Manufacturer.

1. General information to be supplied by the Manufacturer with the proposal (on Attachment C or equivalent).

a. Calculated shipping weight of each structure, subassemblies, and components excluding anchor bolts.

b. Calculated shipping weight of anchor bolts.

c. Maximum groundline reactions (moments, shears, and axial loads, including overload factors) in poles and guy wires.

d. Anchor bolt size, projection, length, and location.

e. Type of material of major components (ASTM number and grade).

f. Description of pole shaft, including thickness, length, diameter, cross-sectional geometry, and method of fastening each shaft component.

g. Method of attaching crossarms, braces, hardware, and miscellaneous appurtenances to structure.

h. Design exceptions.

2. Documentation for approval of Owner or Owner's Representative:

   a. Final design calculations for pole shaft, base plate, anchor bolts, crossarms, and other appurtenances, including their connections for all structures.

   b. The following specific items shall be supplied:

      o For each loading case, the total shears and axial forces, moments, stresses, deflections, section moduli, cross-sectional areas, safety factors (allowable stress/actual combined stresses), the w/t's for polygonal and D/t's for round cross sections at all splices, at all attachment points, at top and bottom, and at least every ten (10) feet along the pole shall be supplied.

      o For each loading case, guy reactions shall be supplied.

      o For the critical loading case, shears and axial forces, moments, stresses, section modulus, cross-sectional area, and safety factor at the arm connections shall be supplied. Deflections at the end of the arm should also be given.

      o Anticipated deflection at the top of the pole and at the end of the arms shall be indicated for each pole for the normal, everyday loading case, without overload factors.

      o For all specified loading cases, all reactions and groundline moments with and without the overload factors shall be supplied.

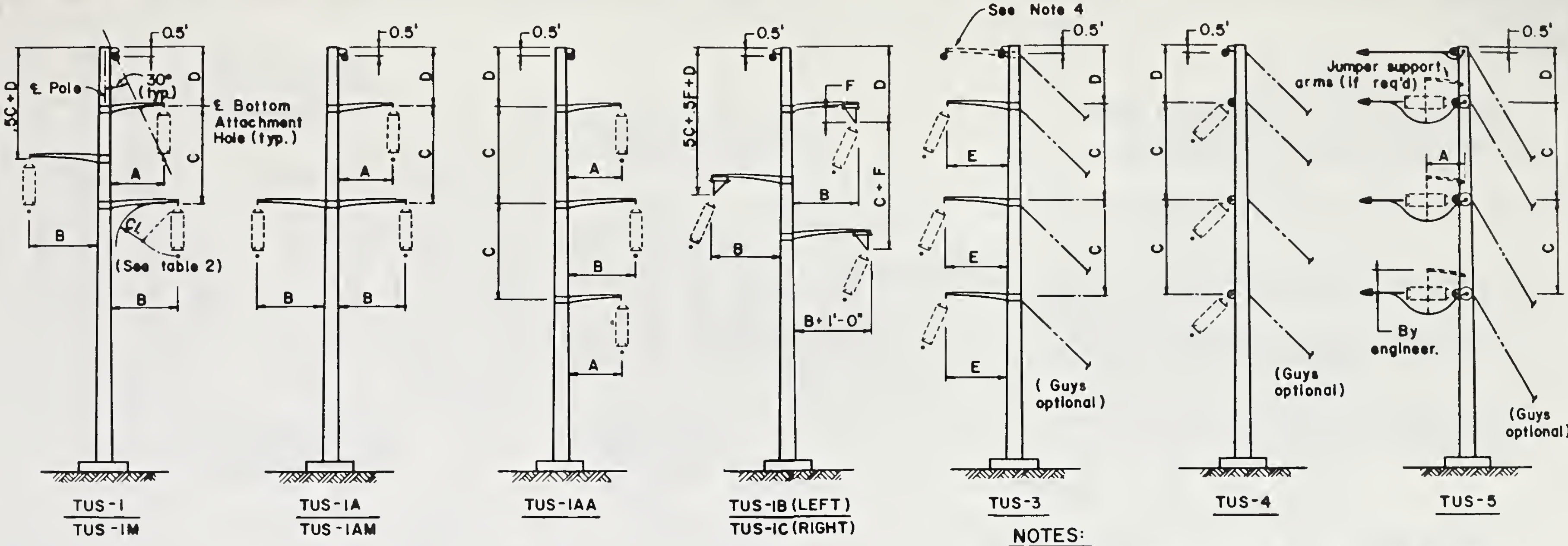
      o Complete design/erection reproducible drawings for each structure type.

      o Identification and weight of each structure - include the weight of components and a bill of materials for each structure.

      o Assembly instructions.

3. Final documentation (as build) after erection of the structures.

4. Test reports (as requested).



NOTES:

1. DIMENSIONS AND CLEARANCES IN TABLES ARE MINIMUMS, GREATER DIMENSIONS MAY BE REQUIRED TO IMPROVE INSULATOR SWING, GALLOPING PERFORMANCE, OR SEPARATION REQUIREMENTS. A 30 DEGREE SHIELDING ANGLE IS ASSUMED. FOR STRUCTURES OF HEIGHTS GREATER THAN 80 FEET, THE SHIELD ANGLE SHOULD BE DECREASED. FOR HIGH ISOKERAUNIC LEVELS OR HIGH GROUND RESISTANCE, USE THE LARGER NUMBER OF INSULATORS (SECOND COLUMN FOR EACH VOLTAGE).
2. A MAXIMUM ALTITUDE OF 3300 FEET ABOVE M.S.L. IS ASSUMED. FOR HIGHER ALTITUDES, CLEARANCES IN TABLE 2 SHOULD BE INCREASED.
3. THE NUMBER OF INSULATORS IN TABLE 2 ARE FOR TANGENT AND SMALL ANGLE STRUCTURES. FOR ANGLE STRUCTURES TUS-3 AND 4, ONE ADDITIONAL INSULATOR BELL SHOULD BE USED. FOR THE DEADEND STRUCTURES (TUS-5, TUS-1M, AND TUS-1AM), TWO ADDITIONAL BELLS SHOULD BE USED.
4. IF CROSSARMS ARE USED FOR OHGW SUPPORT, DIMENSION "D" MAY BE REDUCED AS LONG AS THE SHIELDING ANGLE IS AS REQUIRED.
5. TYPE 1 END PLATES FOR CROSSARMS ARE TO BE USED WITH TUS-1 AND TUS-1A. TYPE 2 PLATES ARE TO BE USED WITH TUS-1M AND TUS-1AM. SEE DRAWING TM-S1, DETAIL C.
6. FOR STRUCTURES TUS-1B AND TUS-1C, THE LENGTH OF THE CROSSARMS TO THE INSIDE OF THE LINE ANGLE MAY BE LESS THAN THE INDICATED MINIMUM DIMENSIONS IN TABLE 1.

TABLE 1—MINIMUM DIMENSIONS (FEET)

VOLTAGE	115 kv		138 kv		161 kv		230 kv	
NUMBER OF INSULATORS	7	8	8	9	10	11	12	13
A	6.0	7.0	7.0	7.5	8.5	9.0	10.0	10.5
B	7.0	8.0	8.0	8.5	9.5	10.0	11.0	11.5
C	8.0	9.0	9.0	10.0	11.0	12.0	13.0	14.0
D	5.5	6.5	6.5	7.5	8.0	9.0	10.0	11.0
E	AS REQUIRED (BY ENGINEER)							
F	AS REQUIRED (BY ENGINEER)							

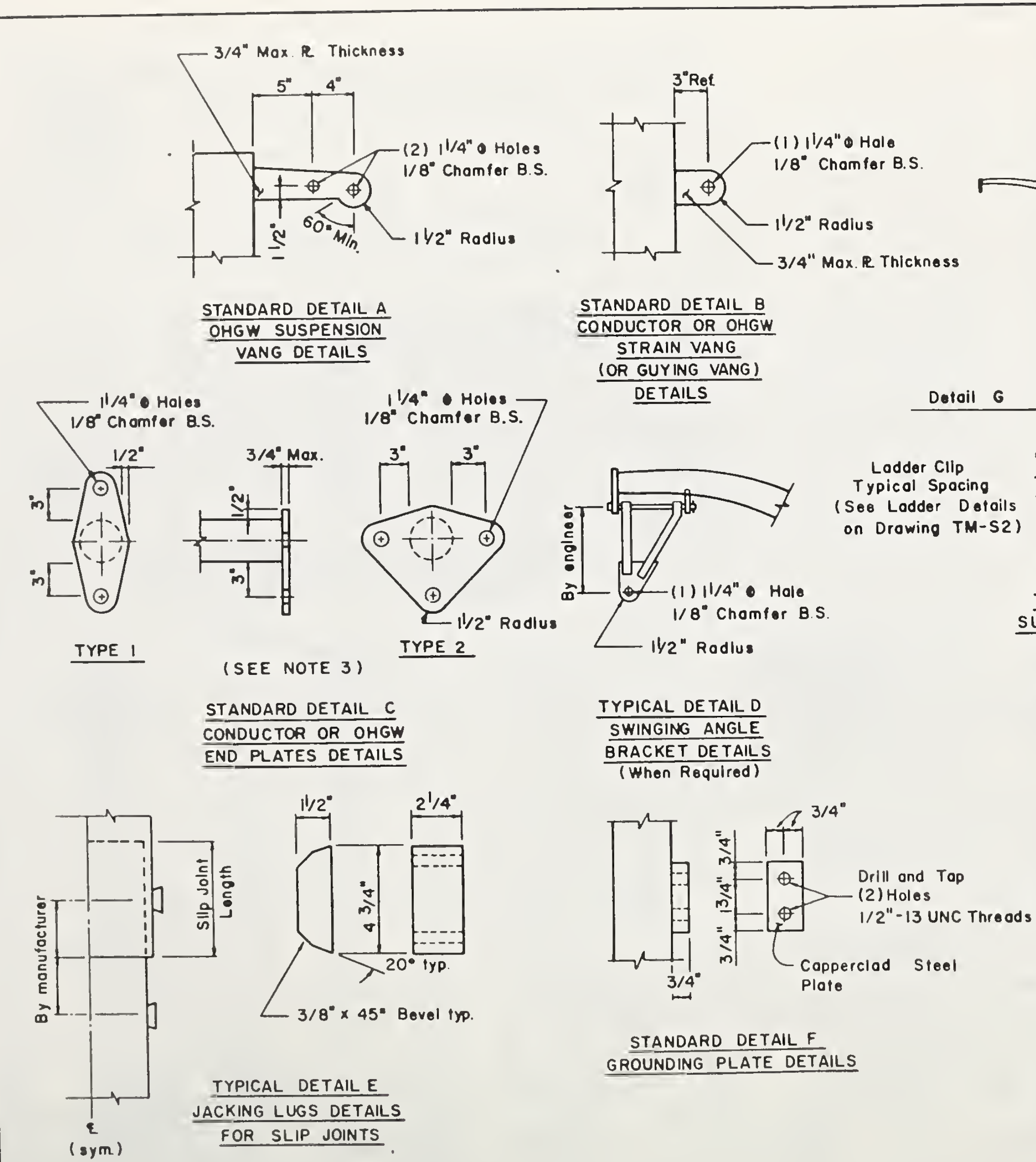
TABLE 2 — MINIMUM CLEARANCES (INCHES)

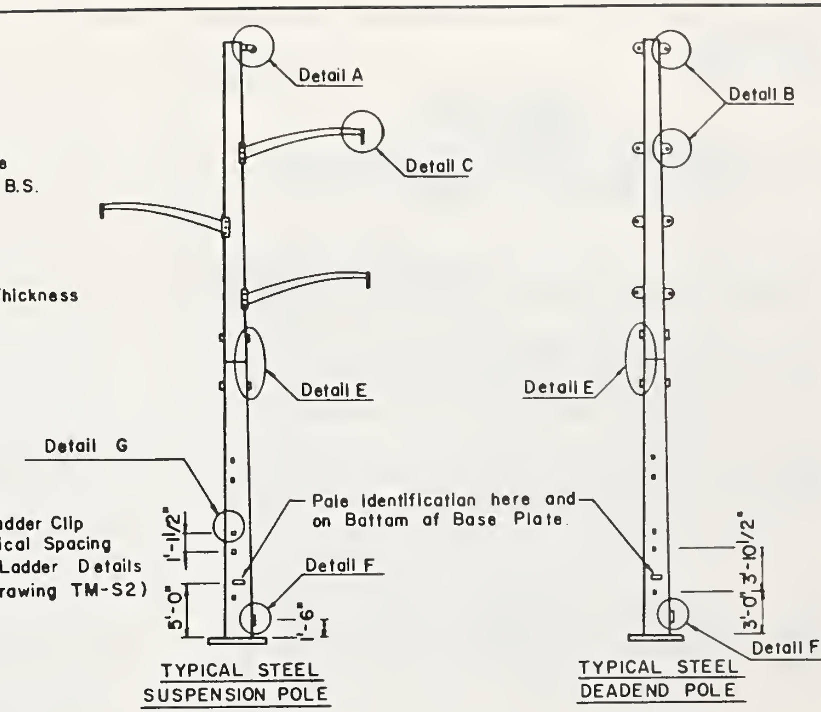
VOLTAGE	115 kv		138 kv		161 kv		230 kv	
NUMBER OF INSULATORS	7	8	8	9	10	11	12	13
NO WIND	42	48	48	54	60	65	71	77
6 PSF WIND	26	26	30	30	35	35	52	52
EXTREME WIND	10	10	12	12	14	14	20	20

TRANSMISSION LINE STRUCTURE

GUIDE FOR STEEL POLE STRUCTURE DIMENSIONS
(115 kv TO 230 kv)

SCALE:		DATE: JAN 82
N.T.S.		TUS SERIES

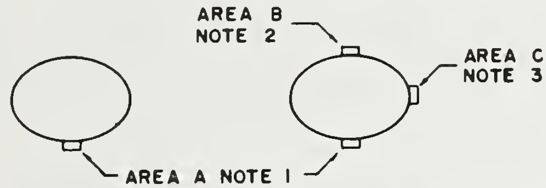




NOTES:

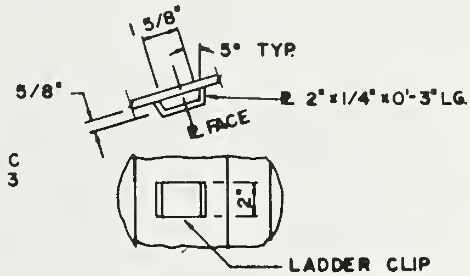
1. CONNECTION DESIGN AND DETAILING TO BE BY FABRICATOR. DETAILS SHOWN HEREON ARE ONLY TYPICAL OF THE SHAPES AND DIMENSIONS DESIRED. FABRICATOR SHALL BE RESPONSIBLE FOR THE STRUCTURAL ADEQUACY AND PROPER FIT-UP OF ALL PARTS OF THE STRUCTURES.
2. ADDITIONAL OR ALTERNATE ATTACHMENTS NOT SHOWN HEREON (SUCH AS GROUNDING CONNECTIONS, PERMANENT CLIMBING DEVICES, ETC.) MAY BE REQUIRED; THESE SHALL BE SHOWN BY THE ENGINEER ON A SEPARATE DRAWING.
3. TYPE 1 END PLATES ARE TO BE USED FOR TUS-1 AND TUS-1A STRUCTURES. TYPE 2 ARE FOR TUS-1M AND TUS-1AM STRUCTURES.

TRANSMISSION LINE STRUCTURE		
GUIDE FOR STEEL POLE STRUCTURE DETAILS		
SCALE: N.T.S.		DATE JAN. 82 TM-S1

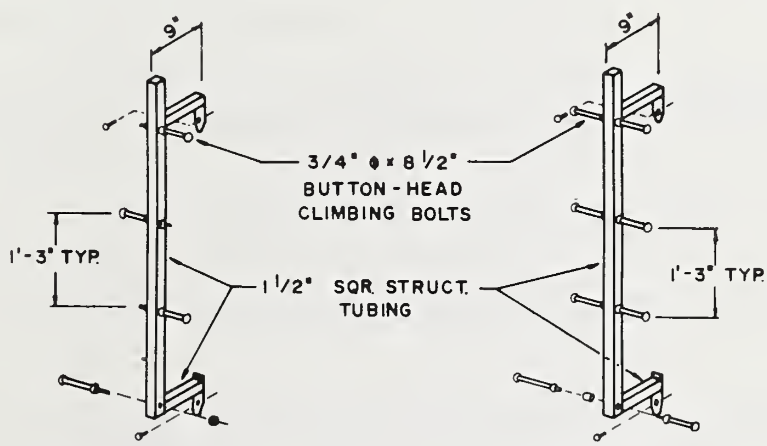


SECTION AA

SECTION BB



STANDARD DETAIL G
STANDARD LADDER
CLIP DETAIL



CLIMBING LADDER

WORKING LADDER

STANDARD LADDER DETAILS

NOTES:

1. MOUNT LADDER CLIPS ON LONGITUDINAL FACE FROM 3'-0" ABOVE BASE PLATE TO TOP OF POLE.
2. MOUNT LADDER CLIPS ON LONGITUDINAL FACE FROM A POINT 15'-0" BELOW BOTTOM CONDUCTOR ASSESMBLY ATTACHMENT TO TOP OF POLE.
3. MOUNT TWO LADDER CLIPS ON TRANSVERSE FACE CROSSING ZONE 15'-0" BELOW BOTTOM CONDUCTOR ASSEMBLY ATTACHMENT.
4. MOUNTING OF LADDER CLIPS ON STRUCTURES OTHER THAN TANGENT STRUCTURES SHOULD BE AS SPECIFIED BY THE ENGINEER.

TRANSMISSION LINE STRUCTURE		
GUIDE FOR STEEL POLE STRUCTURE DETAILS		
SCALE		DATE: JAN. 82
N.T.S.		TM-S5

Technical Specification
for
Steel Pole Structures

1.0 Scope

This Specification covers the design, materials, welding, inspection, protective coatings, drawings and delivery of steel transmission single pole structures. The proposal submitted by the Manufacturer shall include field bolts, locknuts, vangs, attachment provisions for arms and/or insulators, anchor bolts, base plates, and other necessary items to make a complete structure.

2.0 Codes and Standards

Codes, standards, or other documents referred to in this Specification are to be considered as part of it. In the event of conflict between this Specification and referenced documents, or between several referenced documents, the requirements of this Specification shall take precedence or the more stringent requirement shall be followed. If clarification is necessary, contact the Owner or Owner's Representative.

The following codes and standards are referenced:

a. American Institute of Steel Construction (AISC), Specification for the Design, Fabrication and Erection of Structural Steel for Buildings latest edition.

b. National Electrical Manufacturer's Association (NEMA), Tapered Tubular Steel Structures, Standards Publication TT-1, latest edition.

c. American Society for Testing and Materials (ASTM), various standards, latest revisions.

d. American Concrete Institute (ACI), Building Code Requirements for Reinforced Concrete, ACI 318, latest edition.

e. American Welding Society (AWS), Structural Welding Code, AWS D1.1, latest edition.

3.0 General Requirements

The design, fabrication, allowable stresses, processes, tolerances and inspection shall conform to NEMA Standard TT-1, Tapered Tubular Steel Structures with the following additions and/or exceptions:

3.1 Design

a. Pole designs shall be prepared from the attached configuration drawings and design loads. The structure shall be capable of withstanding all specified loading cases including secondary stresses from foundation movements when specified, but not considering the possible restraining effect

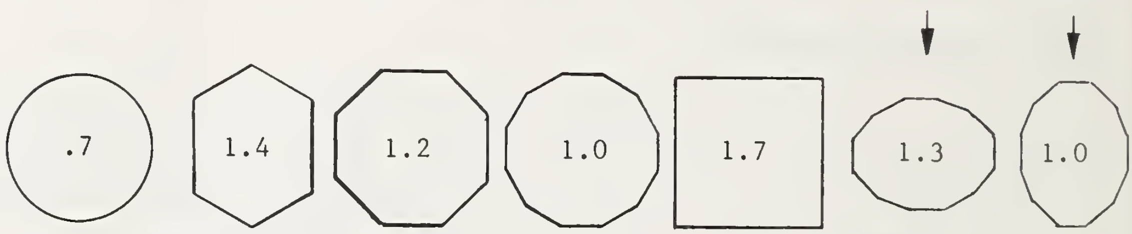
of conductors or shield wires. The structure shall withstand the loads without failure or permanent distortion.

b. Wind pressures shown in the loading criteria shall be multiplied by the appropriate shape factor applied to the poles. Pressures in psf shall be computed as follows:

$$p = W \times C_d$$

Where p = pressure on projected area of the pole normal to wind, W = wind pressure, and C_d = shape (or drag) factor.

Shape factors for computing the wind on poles shall be as follows:



c. The maximum design unit stress shall be the minimum yield strength as stated in applicable ASTM specifications for the particular application and types of loads, including overload factors.

d. Poles shall be designed with a minimum number of joints. No field welding will be allowed. The shaft joints to be made in the field shall be slip joints. Bolted flange joints may be used for guyed structures. Slip joint length shall be at least 1-1/2 times the largest inside diameter of the female section.

Jacking lugs and permanent match marks shall be provided at all slip joints sufficient to insure proper alignment and complete overlap of the joint.

e. The ultimate load in guys shall not exceed 65 percent of the rated breaking strength of the guy.

f. Design of anchor bolts shall be in accordance with the ACI-318-Latest Edition, Building Code Requirements for Reinforced Concrete, assuming a concrete strength as specified by the Owner.

When anchor bolts are specified, they shall have the top 24 inches galvanized. Anchor bolts shall be threaded at the top end a distance sufficient to provide for leveling or raking of the structure. Each anchor bolt shall include two heavy hex nuts.

Welding on anchor bolts will only be allowed in the bottom 12 inches. Only one length of anchor bolt shall be used on each pole. Anchor bolts/clusters shall be plainly marked to indicate the structure type, number, etc.

g. Minimum plate thickness for all pole components above the groundline shall be 3/16".

h. Structures which are to be direct embedded shall have bearing plates and ground sleeves. Bearing plates and all steel below the groundline shall be a minimum of 1/4" thick. Bearing plates shall have a diameter not more than 2" greater than the maximum pole diameter. Galvanized poles shall have a drain hole at the bottom. When a painted finish is specified, poles shall be hermetically sealed. Ground sleeves shall have a minimum length of two feet and minimum thickness of 1/4" centered at the groundline.

i. Poles shall have nearly a uniform taper throughout their entire lengths. The maximum difference in tapers between two pole sections measured by the diameters shall be .20"/ft. for poles with variable taper.

j. Poles with elliptical cross sections shall have a minor axis equal to at least 75 percent of the major axis.

k. All angle poles shall be precambered or raked to remain plumb when the deflection at the top of the pole exceeds one percent of the pole height under a loading of 60°F, no wind and no overload factors. Pole height shall be the height of the pole from the top of the baseplate or designated groundline to the top. Tangent poles with unbalanced vertical loadings shall be precambered for the previously stated conditions.

l. Crossarms shall be designed such that the end of the crossarm is at the specified height under a loading of 60°F, no wind, and no overload factors.

Crossarms shall be upswept or straight tapered steel tubular members, of any cross-sectional type, which meet the dimensions shown on the attached drawings. Arms shall be field bolted to connection plates factory welded on the pole shaft.

Arm end plate connection details for hardware attachment shall be typical of those shown on the attached drawings. The arms shall be hermetically sealed when a painted finish is specified. Galvanized arms shall have drain holes where appropriate.

m. Lifting lugs are optional. The manufacturer shall supply all instructions necessary for handling and erection of poles and crossarms.

n. In the design of connections for vangs, brackets, or stiffeners attached to the pole shaft, care shall be taken to distribute the loads sufficiently to protect the wall of the pole from local buckling.

o. Each pole shall be permanently marked on the pole shaft at approximately eye level and on the bottom of baseplate or bearing plate with the following identifying information: structure type, height, number, and ultimate groundline moment. The method of identification shall be approved by the Owner.

p. A two-hole, NEMA-drilled, copper clad grounding pad shall be welded to the pole shaft 18 inches above the base plate, or in cases of direct embedded poles, 18 inches above the groundline. Grounding pad face shall not be painted.

q. Clips for removable ladders shall begin not closer than 3 feet above the base plate or 3 feet above ground for a direct embedded pole and extend to the top of the pole. Permanent clips shall be designed to support a man and equipment weighing 500 pounds. The clips shall be welded to the pole surface.

r. Application requirements:

1. Pole deflection limitations and means of achieving ____________

2. Foundation type ____________

3. Design concrete compressive strength (psi) ____________

4. Maximum anticipated foundation rotation (degrees) ____________ and maximum anticipated foundation deflection at the groundline (inches) ____________

   (If different for individual loading cases, indicate quantities in loading tables, Attachment A)

5. Special Charpy requirements ____________

6. Maximum diameter (point-to-point) at groundline (inches) ____________

7. Maximum taper (inches/foot) based on total difference between top and bottom diameters ____________

8. Surface protection desired ____________

   If painted, color desired ____________

9. Climbing device desired and quantity ____________

10. Component weight and/or length restrictions ____________

11. Delivery schedule and F.O.B. destination ____________

(If additional space is required, attach separate sheet with reference notation.)

3.2 Materials

a. All materials shall comply with the applicable requirements of ASTM specifications. Any modifications to ASTM specifications must be approved by the Owner's Representative prior to bidding.

b. Poles, arms and conductor brackets shall conform with ASTM A36, ASTM A572, ASTM A588, or ASTM A595.

c. Base plate shall conform with ASTM A572, ASTM A588, ASTM A633, or ASTM A36.

d. Anchor bolts shall conform to ASTM A615, Grade 60 or 75.

e. Other bolts and nuts shall be ASTM A307, ASTM A325, ASTM A354, ASTM A394, or ASTM A687. Locknuts shall be provided for each structure bolt, or ANCO type self-locking nuts may be used. Locknuts shall be the galvanized MF type.

f. Anchor bolt, structural plate, and weld material shall meet NEMA requirements for Charpy tests.

g. For galvanized structures, steel used for the pole shaft and arms shall have a silicon content less than .06 percent.

3.3 Fabrication

a. All welding shall be in accordance with the American Welding Society Code AWS D1.1, latest edition. Welders shall be qualified in accordance with AWS D1.1 welding procedures.

b. One hundred percent penetration welds shall be required in, but not limited to, the following areas:

- o circumferential welds joining structural members
- o longitudinal welds in the female portion of the joint within the slip joint area
- o welds at the butt joints of back-up strips
- o base plate to shaft weld

c. Full penetration or equivalent 90 percent partial penetration with fillet overlay shall be used for arm-to-arm base, vang-to-plate shaft, and arm box joints.

d. Quality and acceptability of every inch of the full penetration welds shall be determined by visual and ultrasonic inspection.

e. All other penetration welds shall have 60 percent minimum penetration. Quality and acceptability of all welds other than full penetration welds shall be determined by visual inspection, supplemented by magnetic particle or dye penetrant inspection.

f. All weld back-up strips shall be continuous the full length of the welds. Care shall be exercised in the design of welded connections to avoid areas of high stress concentration which could be subject to fatigue or brittle fractures.

g. No field welding will be permitted.

h. All parts of the structure shall be neatly finished and free from kinks or twists. All holes, blocks and clips shall be made with sharp tools and shall be clean-cut without torn or ragged edges.

i. Before being laid out or worked in any manner, structural material shall be straight and clean. If straightening is necessary, it shall be done by methods that will not injure the metal.

j. Shearing and cutting shall be performed carefully and all portions of the work shall be finished neatly. Copes and re-entrant cuts shall be filleted before cutting.

k. All forming or bending during fabrication shall be done by methods that will prevent embrittlement or loss of strength in the material being worked.

l. Holes for connection bolts shall be 1/8 inch larger than the nominal diameter of the bolts. Holes in base plates for anchor bolts shall be 3/8 inch larger than the nominal diameter of the anchor bolts. The details of all connections and splices shall be subject to the approval of the Owner or his Representative.

m. Holes in steel plates which are punched must be smooth and cylindrical without excessive tear-out or depressions. Any burrs that remain after punching shall be removed by grinding, reaming, etc.

n. Holes of any diameter may be drilled in plate of any thickness. Care shall be taken to maintain accuracy when drilling stacks of plates.

o. Holes may be made by use of a machine-guided oxygen torch. Flame-cut edges shall be reasonably smooth and suitable for the stresses transmitted to them.

p. The overall length of the assembled structure should not be less than minus 6 inches of the specified length.

3.4 Finishes

a. The following finishes are acceptable: galvanizing, zinc primer and painting, weathering steel, and coal tar epoxy.

Galvanizing - All structures and structural components which are hot-dip galvanized shall meet all the requirements of ASTM A123 and ASTM A153. Measures shall be taken to prevent warping and distortion according to ASTM A384 and to prevent embrittlement according to ASTM A143. Poles made of ASTM A588 steel shall not be galvanized due to the high silicon content of the steel. One gallon of zinc-enriched paint shall be provided with each five poles.

Zinc Primer and Painting - Poles which are to be painted shall be hermetically sealed to prevent corrosion of interior surfaces. After shot or sand blasting and cleaning in accordance with the Steel Structure Painting Council's Surface Preparation Specification, SSPC-SP6, a zinc primer of 3 mils dry film thickness (DFT) and two coats of finish paint, each 3 mils DFT shall be applied to all exterior surfaces in accordance with the paint supplier's recommendations. One gallon each of primer and finish paint shall be supplied with each five poles. A guarantee against flaking or fading of the paint for a minimum of five years shall be provided.

Weathering Steel - Steel shall conform to ASTM A588. After fabrication, poles made of weathering steel shall be cleaned of oil, scale, etc., in accordance with the Steel Structure Painting Council's Surface Preparation Specification, SSPC-SP6, to insure uniform and rapid formation of the protective oxide layer.

Coal Tar Epoxy - When poles are to be directly embedded, a uniform coating of 16 mils thick shall be applied on the exposed surface of the embedded portion of the pole. The coating shall extend from the butt to 12" above the groundline.

b. Bolts and nuts with yield strengths under 100,000 psi shall be hot-dip galvanized per ASTM A153 and ASTM A143, or mechanically coated with zinc in accordance with ASTM B454, Class 50. Bolting materials with yield strengths in excess of 100,000 psi shall not be hot-dip galvanized. Instead, they shall be painted with zinc-enriched paint or mechanically coated with zinc per ASTM B454, Class 50.

c. Compliance with coating thickness requirements shall be checked with a magnetic thickness gauge.

3.5 Inspection and Testing

a. The Owner and his designated agents shall have free entry at all times while work is being carried on, to all parts of the Manufacturer's plant to inspect any part of the production of the poles covered by this Specification.

b. Steel members which are bent or warped or otherwise improperly fabricated shall be properly repaired or replaced.

c. The cost of tests made by the Manufacturer (except full-scale load tests on poles), including cost of the certified test reports shall be considered included in the price.

d. The Manufacturer shall make tests in accordance with ASTM A370 and ASTM A673 to verify that the material used in the structures meets the impact properties.

e. Mill test reports showing chemical and physical properties of all material furnished under this Specification shall be maintained by the Manufacturer for a period of five years and shall be traceable to the structure.

f. All plates over 1-1/2 inches thick shall be ultrasonically tested to assure against defects which could lead to laminar tearing.

g. Welders or welding operators shall be qualified in accordance with the provisions of AWS D1.1.

h. The Manufacturer shall make certified welding reports for each structure. The reports covering welding shall include all welds of a structure. Each weld shall be clearly identified; and the report shall consist of the method of testing, whether the weld is acceptable, the identification of the structure, the date, and the name and signature of the inspector.

3.6 Structure Testing

a. The structures are to have full-scale load tests performed on them as follows:

Structure Type	No. of Load Cases to be Tested
____________	____________
____________	____________

b. Details of the test procedures and methods of measuring and recording test loads and deflections will be specified by the Manufacturer prior to testing and will be subject to the review and approval of the Owner or his Representative.

c. Deflections shall be recorded in the transverse and longitudinal directions when applicable. Deflection measurements shall be taken under the no load condition both before and after testing.

d. Material procurement for test poles shall be identical to material procurement procedures for regular production run poles.

e. A full report listing results shall be submitted after completion of all testing. Copies of mill test reports shall be included in the load test report. The report shall also include a complete description of the load tests with diagrams and photographs.

3.7 Shipping

a. Each shipment shall be accompanied by a list of all parts, identifiable by structure type and number. Arms, bolts and miscellaneous hardware will be identified by the list for matchup with the respective pole shaft. All parts required for any one structure shall be in one shipment if possible.

b. The Owner and Owner's Representative shall be notified prior to shipment that such shipment is to take place, and they reserve the right to inspect the components prior to shipment. The notification shall give quantities, weight, name of common carrier used, and expected time of arrival.

c. Anchor bolts shall be preclustered or shipped loose and furnished with top and bottom templates. Bolt clusters shall be rigid enough to withstand the normal jolts of shipping and handling with no displacement of bolts from the proper positions within the cluster.

4.0 Information to be Supplied by the Manufacturer

4.1 Information and Drawings to be Supplied with the Proposal (Attachment C)

a. Calculated shipping weight of each structure excluding anchor bolts. Separate weights shall be given for arms and poles.

b. Calculated shipping weight of anchor bolts.

c. Ultimate groundline reactions (including O.C.F.) in poles and guy wires.

d. Anchor bolt size, length and locations (bolt circle diameters).

e. Type of material of major components (ASTM number).

f. Description of pole shaft, including thickness, length, diameter, cross-sectional geometry, and method of fastening each shaft component.

g. Data showing the design of the arm, arm connections, arm attachment plates and brackets.

h. Sketches or draft drawings of structure and structure attachments.

4.2 Documentation to be Supplied to the Owner for his Approval Prior to Fabrication

Final design calculations for pole shaft, base plate, anchor bolts, crossarms, and other appurtenances, including their connections for all structures.

The following information shall be supplied:

a. For the loading cases with overload factors, the total shear, axial forces, moments, stresses or stress ratios, section moduli, cross-sectional areas, deflections, w/t's for polygonal and D/t's for round cross sections at all splices, at arm attachment points (top and bottom), and at least every ten (10) feet along the pole.

b. For the critical loading case, shear and axial forces, moments, stresses, section moduli, and cross-sectional areas at the arm connections; bolt stresses in the arm connection; and deflection at the end of the arm.

c. Anticipated deflections at the top of the pole and at the ends of the arms shall be indicated for each pole for the normal, everyday loading condition of 60^{o}F, no wind, no overload factors.

d. For all specified loading cases, reactions and groundline moments shall be supplied.

e. Detail drawings for each structure type giving weights of structure components, dimensions, and bill of materials.

f. Assembly instructions and erection drawings.

4.3 Final Documents shall be supplied to the Owner for the items in Section 4.2.e, after erection of all structures and prior to final payment.

4.4 Test Reports (as requested)

a. Certified mill test reports for all structural material.

b. Certified welding reports for each structure.

c. Impact property test reports showing that the material used in the structures meets the impact properties.

d. Test reports on coating thickness.

e. Report of structure testing, when required, including photos, diagrams, load trees, etc.

5.0 Approval, Acceptance and Ownership

5.1 Final designs must be approved by the Owner or Owner's Representative before material ordering and fabrication. Material ordering and fabrication prior to approval will be at Supplier's risk. It is understood that award of this contract does not constitute acceptance of design calculations submitted with the bid and that if corrections are required in the final structure designs due to Manufacturer's errors, omissions, or misinterpretations of the Specifications, the quoted price shall not change. Approval of the drawings and calculations by the Owner or his Representative does not relieve the Supplier of responsibility for the adequacy of the design, correctness of dimensions, details on the drawings, and the proper fit of parts.

5.2 After delivery, the poles will be inspected and shall be free of dirt, oil blisters, flux, black spots, dross, tear-drop edges, flaking paint or zinc; and in general, shall be smooth, attractive, and unscarred. Poles not meeting this requirement shall be repaired or replaced by the Fabricator at no additional cost to the Owner.

5.3 All final drawings shall become the property of the Owner, who shall have full rights to reproduce drawings and use them as he sees fit, including submitting them to other vendors for the purpose of obtaining bids on future steel pole purchases.

STRUCTURE DIMENSIONS AND OTHER REQUIREMENTS

a. ARM DESIGN-CLEARANCE REQUIREMENTS

Insulator String Length ________ in.

Loading Condition	Swing Angle	$C_{1,2,3}$ (in.)
ϕ_1. Normal		
ϕ_2. 6 lb.		
ϕ_3. High Wind		

b. SHIELD ANGLE IS ________

c. GUY INFORMATION

Guy Size:

R.B.S.: Lead:

d. ARM DIMENSIONS

Arm	Length	Arm	Length

e. POLE DIMENSIONS

Dim.	TOTAL POLE LENGTH							
L_1								
L_2								
L_3								
L_4								
L_5								
L_6								

f. LOAD INFORMATION

Design Spans: V.S. H.S. Ruling:

Line Angle: Max. Min.

CONDUCTOR: Description of Load	°F	Unit Loads Vert.	OCF	Trans	OCF	Long. Loads	OCF	Tensions KIPS	OCF

OHGW:									

TRANSMISSION LINE STRUCTURE

DESIGN LOADS (CONDUCTOR- OHGW- V.S., H.S.)

a. LOADS WITH OCF

DESCRIPTION OF LOAD	TEMP °F	LOAD IN KIPS (INCLUDES O.C.F.)												w psf	Δ_g	θ_g
		V_1	T_1	L_1	V_2	T_2	L_2	V_3	T_3	L_3	V_g	T_g	L_g			

b. LOADS WITHOUT OCF

DESCRIPTION OF LOAD	TEMP °F	LOAD IN KIPS												w psf	Δ_g	θ_g
		V_1	T_1	L_1	V_2	T_2	L_2	V_3	T_3	L_3	V_g	T_g	L_g			

COMMENTS:

1. "w" is for a shape factor of 1.0.

V_1 = Vertical load, kips
T_1 = Transverse load, kips
L_1 = Longitudinal load, kips
w = Wind load on the pole, psf
θ = Rotation at the groundline
Δ = Deflection at groundline

TRANSMISSION LINE STRUCTURE

8.0 Preliminary Design Information (To be Completed by the Manufacturer)

ATTACHMENT C

I. POLE DESIGN

DESCRIPTION		STRUCTURE HEIGHT					
Diameter Taper (in/ft)							
Diameter Taper (in/ft)							
Diameter Taper (in/ft)							
Bottom Diameter (in)							
Top Diameter (in)							
Cross Section Type							
Material Thickness (in)							
Material Thickness (in)							
Material Thickness (in)							
ASTM	Material						
	Grade						
Gov. Load Case(s)							
Max. Moment at Groundline							
Max. Shear at Groundline							
Max. Axial at Groundline							
Max. Load in Guy							
Anchor Bolts	Size/Spacing						
	Length						
	Cage Dia.						

II. ARM DESIGN

DESCRIPTION		ARM TYPE AND DATA					
		A	B	C	D	E	OHGW
Taper (in/ft)							
End Diameter (in)							
Diameter at Pole (in)							
Cross Section Type							
ASTM	Material						
	Grade						
Gov. Load Case(s)							
Mom. at Pole (kip-ft.)							

III. SUMMARY

ITEMS	STRUCTURE HEIGHTS					
Arms (total)						
Pole						
Anchor Bolts						
Total Wt. / Structure						
Total Cost / Structure						
Total Weights						
Total Costs						

COMMENTS:

TRANSMISSION LINE STRUCTURE

APPENDIX A

COMMENTARY

COMMENTARY ON GUIDE SPECIFICATIONS FOR STEEL POLE STRUCTURES

A. GENERAL

The necessity of a clear bid specification for the purchase of steel poles is very important to the bid evaluation process and the acquisition of structurally adequate poles. The specification should contain sufficient requirements and information so that all bids can be evaluated equally and so that the Fabricator clearly understands what is expected of him.

The basis of the technical Specification is NEMA Standard TT-1, Tapered Tubular Steel Structures, with additions and/or exceptions made to the NEMA specification. There are several items in the Specification which need further explanation.

B. SECTION 3.1 DESIGN REQUIREMENTS

3.1.a Loads

The primary loads for transmission pole structures are weather loads and erection loads. Erection loads are determined by the Manufacturer and included in its design. Weather loads must be clearly specified by the Owner. The location and direction of loads should be indicated in a loading agenda or loading trees, and should have units of newtons, pounds, or kips (or for uniform wind loads on the structure, pascals, lbs./ft.^{2}, or kips/ft.^{2}). The specifying of loads in the form of general environmental criteria such as wind velocity or radial thickness of ice, is insufficient. Not only is there difficulty in evaluating bids, but there also is a greater possibility of error in calculated design loads.

ASCE Publication on the Design of Steel Transmission Structures, Section 1.0, describes different load conditions. Overload factors for NESC light, medium, and heavy loading districts should be at least equal to those given in the latest edition of NESC for Grade B construction. Overload factors for extreme ice and extreme wind shall be at least 1.1. The load factors suggested for extreme conditions are made with the idea that testing of the structure will be to the calculated loads with a load factor of 1.0. The everyday load for 60^{o}F no wind should be given in the loading agenda so that davit arms and/or camber of a pole can be properly designed.

P-Δ Moments

The NEMA specification requires the Fabricator to include in its analysis the secondary moment due to the unbalanced vertical load. Whenever there is a transverse or longitudinal load, the pole will

deflect in the direction of the load. As a result, the vertical load is no longer in its original position. It has moved over as the pole deflected, causing additional moments (sometimes called P-Δ moments). As required by the NEMA specification, this Specification requires this moment to be included in the analysis. The deflection and resulting P-Δ moment should be calculated for the loads (including overload factors) indicated in the loading agenda.

Foundation Rotation and Deflection

This Specification allows the User the option of specifying a foundation rotation, either as a maximum for all load cases or as a certain amount for each load case. For purposes of bidding and design, the Engineer also has the option to simply specify a fixed base with no foundation rotation or deflection.

When specifying the maximum value for the foundation rotation and deflection for all load cases, the Engineer establishes performance requirements for the steel pole and foundation. In determining this value, the Engineer may consider aesthetics, phase-to-structure clearances, ground-to-phase clearances, or even the ability to replumb a structure.

The specifying of a rotation and deflection for each load case is a refinement in analysis and design which allows the User to match types and probability of loads with foundation response. For instance, under a 100-year extreme wind load, one may allow more foundation deflection and rotation than under NESC heavy loading district loads.

In the case where foundation rotation-deflection is specified, the Manufacturer should include such effects in his calculations of final deflected pole stresses (P-Δ effects). The rotation and deflections when specified should be for the respective loads with overload factors.

Longitudinal Loads

Because steel poles are flexible structures, there may be a reduction in induced moments in a pole under some types of longitudinal loads due to the restraining effect of the overhead ground wires. Traditionally, static longitudinal loads are specified due to the complexity of calculating the influence of structure flexibility. The results of the EPRI project, Longitudinal Loads on Transmission Line Structures, published in August 1978, suggest design procedures for longitudinal load analysis, taking into account deflections of wires, insulators, and structures. Design curves have been developed and can be used to approximate the longitudinal loading on the arm and structure for given line systems. Although the EPRI project is extremely worthwhile, utilization of these results by some of the bidders does present certain difficulties in bid evaluation.

In order to be certain that steel pole bids can be evaluated on an equal basis, this Specification requires that all longitudinal loads specified in the loading agenda are not to be reduced due to flexibility of the structure. If the Borrower wishes to take advantag of structure flexibility, then the Owner's Engineer should estimate structure and line parameters. Using the design approach suggested in the EPRI project, the longitudinal design loads should then be specified on the loading trees. It is felt that this approach is better than having the steel pole Manufacturers account for structure flexibility since: (1) not all Manufacturers have the capability to perform such an analysis, (2) the Consultant will have to evaluate the Manufacturer's design anyway, and (3) plan and profile drawings would have to be included in the contract documents so that proper evaluation of the effect of longitudinal loads between deadends can be made.

3.1.b Shape Factors

Shape factors (drag coefficients) have been established for various pole cross sections so that Manufacturers will be designing on the same basis. More refined drag coefficients can be found in Table 1.2.5c of the Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals. These drag coefficients are a function of wind velocity, diameter, and shape of the member. If the User modifies this section of the Specification in order to reflect more refined drag coefficients, the User should be certain to provide all additional information needed to clearly and precisely define the loads.

3.1.e Guy Wires

Any time a steel pole structure is guyed, the guy type and size and guy lead must be specified. The Manufacturer needs this information to properly analyze the structure. This Specification limits the load in the guy to 65 percent of its ASTM rated breaking strength.

In design, the loads with the respective overload factors are applied at appropriate locations on the guyed structure. The reactions in the guys must be less than 65 percent of the capacity of the guy.

3.1.j Ratio of Minor to Major Axis

Longitudinal loads are sometimes difficult to determine. In order to reduce the chances of a cascading failure in a tangent structure, this Specification requires the minor axis of an elliptical or rectangular section to be not less than 75 percent of the major axis. This requirement will provide inherent longitudinal strength for steel pole tangent structures. In most instances, this inherent longitudinal strength is naturally provided in the design process.

3.1.o Wind Induced Vibrations

Members of all types of transmission structures may occasionally be subject to wind induced vibrations. The manufacturer should detail each structure using good design practices considering this possibility. If vibrations are experienced, the owner should add additional damping to the structure. Damping may be particularly important on structures which are to be installed without conductors for an extended period of time.

C. SECTION 3.2 MATERIALS

3.2.f Charpy Requirements

A Charpy test is a notch-bar impact test used to compare notch sensitivities of materials. The impact values cannot be converted into energy figures for use directly in engineering design. The impact value from the notch-bar impact test is used only as a comparison test. For example, if a type of steel has been found to have a good notch toughness in service and its impact value is known, it is assumed that other types of steels having the same impact value will also have the same notch toughness. NEMA has established impact values for the Charpy notch-bar impact test. These values are a function of yield stress, plate or bar thickness, and temperature.

Notch impact tests are used to help determine if a normally ductile material might behave in a brittle behavior. Three main factors which influence if a material will behave in a brittle or ductile manner are triaxiality, strain rate, and temperature. Ductile materials tend to become more brittle as triaxiality increases, strain rate increases, or temperature decreases. Since brittle materials require far less energy for fracture than ductile materials of the same strength, one can realize the importance of the Charpy test for steel poles used on transmission lines.

The tendency is to reduce temperature requirements of the Charpy test for structures to be in service in warm climates such as Louisiana or Florida. This is not recommended. However, for locations in which temperatures may be extremely low, lower temperature values may need to be specified.

The NEMA specification contains Charpy requirements for structural plate, anchor bolts, and weld materials. The material used for making welds is required to meet the impact requirements for the lowest toughness requirements of the plates being joined.

D. SECTION 3.3 FABRICATION

E. SECTION 3.4 FINISHES

Weathering Steel

There are environments where weathering steel is not recommended in a bare, uncoated condition because the protective, tight oxide will not form properly. These environments include: (1) atmospheres containing concentrated corrosive industrial fumes, (2) marine locations subject to salt-water spray or salt-laden fogs, or (3) applications where the steel may be continuously submerged in water (salt or fresh), or buried soil.

In general, weathering steel is intended for and is most often used in a bare, uncoated condition. However, those surfaces that will not be boldly exposed to the weather or subjected to a wet-dry cycle should be protected from corrosion. Flat, horizontal surfaces are particularly vulnerable.

If the pole is to be embedded in concrete, the interface between the pole, concrete, and the atmosphere should be protected in such a way as to prevent leakage between the concrete and steel. Otherwise, moisture would remain and possibly cause corrosion at the same rate as carbon steel.

Coal Tar Epoxy

When poles are direct embedded, the specification requires a coal tar epoxy to be applied to the exterior surface of the embedded portion of the pole. This coating will tend to insulate the pole from the ground and as such, additional grounding may be required.

Additional Protection

The Owner or Owner's Representative should determine if the embedded poles should be protected by anodes. If it is necessary, requirements for anodes and their installation should be incorporated in the construction specification.

F. SECTION 3.5 INSPECTION AND TESTING

G. SECTION 3.6 STRUCTURE TESTING

An option is available in the Specification for full-scale testing of a structure or structures. For a Manufacturer which has been designing and fabricating steel poles with the same processes for a good number of years, the need for testing of a steel pole is questionable. Structure testing may be appropriate in cases where there are unusual requirements, new fabrication techniques, or where there are numerous tangent structures of the same or similar design.

H. SECTION 3.7 SHIPPING

I. SECTION 4.0 INFORMATION TO BE SUPPLIED BY THE MANUFACTURER WITH THE PROPOSAL

In order to properly evaluate bids, the Specification requires certain information to be supplied with the bid. This information may be supplied on the preliminary drawings from the Bidder. If the forms in Attachment B are used, one will be able to quickly review the information on the forms and simultaneously compare the information from the different Manufacturers.

APPENDIX B

EXAMPLES OF
ATTACHMENTS A & B

STRUCTURE DIMENSIONS AND OTHER REQUIREMENTS

a. ARM DESIGN-CLEARANCE REQUIREMENTS

Insulator String Length 70 in.

Loading Condition	Swing Angle	$C_{1,2,3}$ (in.)
ϕ_1. Normal	22°	66
ϕ_2. 6 lb	60°	35
ϕ_3. High Wind	78°	14

b. SHIELD ANGLE IS 30±

c. GUY INFORMATION

Guy Size: N.A.

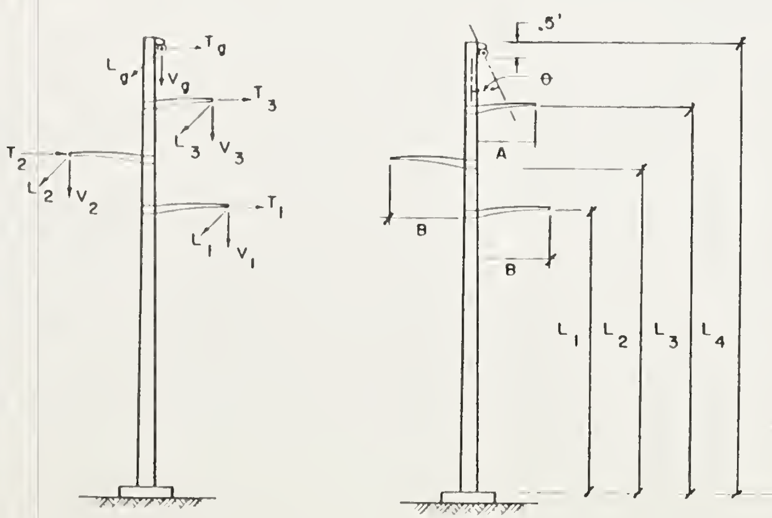
R.B.S.: N.A. Lead: N.A.

d. ARM DIMENSIONS

Arm	Length	Arm	Length
A	9.0		
B	10.0		

e. POLE DIMENSIONS

Dim.	TOTAL POLE LENGTH							
	80	90	100	110				
L_1	59	69	79	89				
L_2	65	75	85	95				
L_3	71	81	91	101				
L_4	80	90	100	110				
L_5								
L_6								



f. LOAD INFORMATION

Design Spans: V.S. 1200' H.S. 900' Ruling: 800'

Line Angle: Max. 0° Min. —

CONDUCTOR: 795 26/7 ACSR		Unit Loads				Long. Loads kips	OCF	Tensions	
Description of Load	°F	Vert.	OCF	Trans	OCF			KIPS	OCF
1. NESC Heavy	0	2.094	1.5	.703	2.5	.7	1.65	13.0	1.65
2. High Wind (21 psf)	60	1.094	1.1	1.939	1.1			10.8	1.1
3. Extreme Ice (1")	32	3.715	1.1					14.8	1.1
4. Unbal. Ice (1"/0")	32	2.405	1.1					3.1	1.1
5. No Load	60							7.7	1.0
6. No Load	32							8.6	1.0

OHGW: 7/16 E.H.S.	°F	Vert.	OCF	Trans	OCF	Long. Loads kips	OCF	KIPS	OCF
1. NESC Heavy	0	.980	1.5	.478	2.5			8.3	1.65
2. High Wind (21 psf)	60	.399	1.1	.761	1.1			6.7	1.1
3. Extreme Ice (1")	32	2.184	1.1					9.6	1.1
4. Unbal. Ice (1"/0")	32	1.291	1.1					2.3	1.1
5. No Load	60							5.9	1.0
6. No Load	32							6.3	1.0

HAR TAP

TRANSMISSION LINE STRUCTURE

TANGENT SUSPENSION

161 kV

Scale		3/10/83
None	Rural Cooperative	TUS-1

DESIGN LOADS

(CONDUCTOR- 795,26/7 ACSR, OHGW-7/16 E.H.S. V.S. 1200' H.S. 900')

a. LOADS WITH OCF

DESCRIPTION OF LOAD	TEMP °F	LOAD IN KIPS (INCLUDES O.C.F.)												w psf	Δ_g	θ_g
		V_1	T_1	L_1	V_2	T_2	L_2	V_3	T_3	L_3	V_g	T_g	L_g			
1. NESC Heavy	0	4.4	1.6	1.2	4.4	1.6	1.2	4.4	1.6	1.2	1.8	1.1	0	10	0	0
2. High Wind (21 psf)	60	1.6	1.9	-	1.6	1.9	-	1.6	1.9	-	.53	.8	-	39	0	0
3. Extreme Ice (1")	32	5.2	-	-	5.2	-	-	5.2	-	-	2.8	-	-	-	0	0
4. Unbalanced Ice (cond)	32	3.6	-	3.41	5.2	-	-	5.2	-	-	2.8	-	-	-	0	0
5. Unbalanced Ice (OHGW)	32	5.2	-	-	5.2	-	-	5.2	-	-	1.5	-	2.5	-	0	0
6. High Wind (no cond)	60													39	0	0
(See Notes Below)																

b. LOADS WITHOUT OCF

DESCRIPTION OF LOAD	TEMP °F	LOAD IN KIPS												w psf	Δ_g	θ_g
		V_1	T_1	L_1	V_2	T_2	L_2	V_3	T_3	L_3	V_g	T_g	L_g			
1. NESC Load	0	2.9	.64	.7	2.9	.64	.7	2.9	.64	.7	1.2	.44	0		0	0
2. High Wind (21 psf)	60	1.45	1.73	-	1.45	1.73	-	1.45	1.73	-	.48	.73	-	39	0	0
3. Extreme Ice (1")	32	4.73	-	-	4.73	-	-	4.73	-	-	2.55	-	-	-	0	0
															0	0
															0	0
															0	0
7. No Load	60	1.46	-	-	1.46	-	-	1.46	-	-	.48	-	-	-	0	0

COMMENTS:

1. "w" is for a shape factor of 1.0.
2. Loads "T" and "L" are reversible.
3. High wind from load case "6" is from any direction.
4. Load case "4" is for any conductor position.
5. Refer to Drwg. on Att. A for load location.

V_i = Vertical load, kips
T_i = Transverse load, kips
L_i = Longitudinal load, kips
w = Wind load on the pole, psf
θ = Rotation at the groundline
Δ = Deflection at groundline

HAR TAP

TRANSMISSION LINE STRUCTURE

Tangent Suspension
161 kV

Scale	Rural Cooperative	3/10/83
None		TUS-1

APPENDIX C

SELECTED SI-METRIC CONVERSIONS

Selected SI-Metric Conversions

AREA

To Convert From	To	Multiply by	
circular mil (cmil)	square meter (m^2)	5.067075	E-10
square centimeter (cm^2)	square meter (m^2)	*1.000	E-04
square foot (ft^2)	square meter (m^2)	*9.290304	E-02
square inch (in^2)	square meter (m^2)	*6.451600	E-04
square kilometer (km^2)	square meter (m^2)	*1.000	E+06
square mile (mi^2)	square meter (m^2)	2.589988	E+06

FORCE

To Convert From	To	Multiply by	
kilogram force (kgf)	newton (N)	*9.806650	
kip	newton (N)	4.448222	E+03
pound force (lbf)	newton (N)	4.448222	

FORCE PER LENGTH

To Convert From	To	Multiply by	
kilogram force per meter (kgf/m)	newton per meter (N/m)	*9.806650	
pound per foot (lb/ft)	newton per meter (N/m)	1.459390	E+01

DENSITY

To Convert From	To	Multiply by	
pound per cubic inch (lb/in^3)	kilogram per cubic meter (kg/m^3)	2.767990	E+04
pound per cubic foot (lb/ft^3)	kilogram per cubic meter (kg/m^3)	1.601846	E+01

LENGTH

To Convert From	To	Multiply by	
foot (ft)	meter (m)	3.048	E-01
inch (in)	meter (m)	*2.540	E-02
kilometer (km)	meter (m)	*1.000	E+03
mile (mi)	meter (m)	*1.609344	E+03

*Exact Conversion.

LOAD CONCENTRATION

To Convert From	To	Multiply by	
pound per square inch (lb/in^2)	kilogram per square meter (kg/m^2)	7.030696	E+02
pound per square foot (lb/ft^2)	kilogram per square meter (kg/m^2)	4.882428	
ton per square foot (ton/ft^2)	kilogram per square meter (kg/m^2)	9.071847	E+02

PRESSURE

To Convert From	To	Multiply by	
kip per square inch (kip/in^2)	pascal (Pa)	6.894757	E+06
kip per square foot (kip/ft^2)	pascal (Pa)	4.788026	E+04
newton per square meter (N/m^2)	pascal (Pa)	*1.000	
pound per square foot (lb/ft^2)	pascal (Pa)	4.788026	E+01
pound per square inch (lb/in^2)	pascal (Pa)	6.894757	E+03

BENDING MOMENT

To Convert From	To	Multiply by	
kilogram force meter (kgf-m)	newton meter (N-m)	*9.806650	
kip-foot (kip-ft)	newton meter (N-m)	1.355818	E+02
pound-foot (lb-ft)	newton meter (N-m)	1.355818	

VELOCITY

To Convert From	To	Multiply by	
foot per second (ft/s)	meter per second (m/s)	*3.048	E-01
kilometer per hour (km/h)	meter per second (m/s)	2.777778	E-01
mile per hour (mi/h)	meter per second (m/s)	4.470400	E-01
meter per hour (m/h)	meter per second (m/s)	2.777778	E-04

*Exact Conversion.

APPENDIX D

REFERENCES

PRIMARY REFERENCES

There is considerable information concerning the design of steel pole structures. The following documents were primarily used in preparation of this Specification. These documents contain extensive bibliographies.

1. American Society for Testing and Materials (ASTM), Philadelphia, PA.

2. National Electrical Safety Code, (NESC), American National Standard ANSI C2-1981, Institute of Electrical and Electronic Engineers, Inc., New York, New York.

3. Specification for the Design, Fabrication, and Erection of Structural Steel for Building, 1969, American Institute of Steel Construction, New York.

4. Standard Publication TT-1, Tapered Tubular Steel Structures, 1977, Rev. June 1978, National Electrical Manufacturers Association, (NEMA).

5. Standard Specification for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 1975, American Association of State Highway and Transportation Officials, Washington, D.C.

6. Structural Welding Code, AWS D1.1, American Welding Society, Miami, FL.

7. Task Committee on Steel Transmission Poles of the Committee on Analysis and Design of Structures of the Structural Division, "Design of Steel Transmission Pole Structures," Journal of the Structural Division, Vol. 100, No. ST12 Proc-Paper 11009, pp. 2449-2518, Dec. 1974, American Society of Civil Engineers.